Health hazards in the built environment and their relationship to childhood neurobehaviourhal disorders – Part 2

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Fluoride

Fluoride's controversial history began in 1945 when it was first introduced into Michigan's drinking water supply. The link between fluoride and a decline in children's intelligence however was first highlighted twenty years ago from several Chinese studies where the levels of fluoride in well water varied significantly amongst the rural communities depending upon their geological conditions[1,2,3,4]. A recent systematic review of 27 studies provided support that ingesting fluoridated water in levels above 1 mg/L may reduce IQ in children by 7 points[5]. This was also observed by Cheng & Lynn (2013) who noted a 6 point reduction in IQ in children ingesting fluoridated water[6]. Consequently fluoride was flagged as a neurodevelopmental toxin linked to neurobehaviourhal disorders in children[7]. This is contrary to a recent NZ study which found no differences in IQ resulting from fluoride, though the authors were employed by the Faculty of Dentistry at the University of Otago, Dunedin, New Zealand[8].

Fluoride is classified as a pharmaceutical drug because it is not an essential nutrient required by the body and it is added to the water to treat a disease (tooth decay). Consequently it was rejected in the drinking water supply of 97% of Western Europe because it was considered unethical to mass medicate an entire population without informed consent. Consequently most countries do not fluoridate their drinking water. Whilst most would agree that topical application of fluoride has been shown to protect against tooth decay, the ingestion of fluoridated water and its role in the prevention of tooth decay remains controversial. Part of this may lie with the fact that toothpaste contains pharmaceutical grade fluoride as opposed to the industrial grade fluoride used in drinking water which is often contaminated with arsenic, lead, radioactive particles and other impurities because it is a by-product from the phosphate fertiliser industry[9].

In contrast to a breast fed infant, a bottle fed infant can receive up to 200 times more fluoride which substantially increases their risk for dental fluorosis[10] because breast milk contains very little fluoride (0.006 ppm)[11]. Subsequently in 2006, the American Dental Association recommended that parents do not prepare infant formula with fluoridated tap water[12]. There are some in the scientific community who argue that there is no adequate margin of safety from known harmful effects associated with fluoride[13].

Wireless Technology

In the past two decades, millions of children in industrialised countries have been exposed to varying levels of radiofrequency radiation from wireless technologies and the deployment of wireless infrastructure both in the school and home environment. These levels are up to 10^{20} magnitude above the original background radiation since the birth of the universe[14]. Given the inherent difficulties and ethics involved in conducting research on children in addition to the ubiquitous and changing nature of wireless technologies (frequency, amplitude, pulse, intensity, polarity and information content), the challenge in identifying biomarkers and the difficulty in establishing a control group, few clinical studies have been conducted on radiofrequency exposure and neurobehaviourhal disorders such as autism spectrum conditions. A recent systematic review concluded that the pathophysiology underpinning autism spectrum conditions are remarkably similar to those found from exposure to radiofrequency electromagnetic energy including but not limited to brain oxidative stress and inflammation, DNA damage, stress proteins, immune abnormalities, calcium channel dysfunction, disturbed circadian rhythms, degraded cognition and compromised blood brain barrier and brain perfusion[15].

Children are uniquely susceptible to the radiofrequency electromagnetic energy (RF EME) used in wireless technologies because unlike adults their skulls are thinner[16], they absorb twice as much microwave radiation[17], they are physically smaller in size, they have a longer lifetime exposure and they undergo rapid cell

division and critical windows of development. This is likely to have serious implications for the developing brain given that neurodevelopment begins in the early prenatal stage with proliferation of radial glia and neurons, and continues to develop until almost 3 years of age[18]. Furthermore myelination is an important process that begins in the second half of gestation and goes on to adolescence, with different systems myelinating at different times.

Australia's standards for radiofrequency electromagnetic fields are based on short term immediate health effects (6 minutes) of heating of tissue established by the International Commission for Non-Ionising Radiation Protection[19]. These outdated guidelines were originally developed in the 1960s based on thermal (heating) considerations in adult military personnel operating radar equipment. Many have questioned the validity of these standards as they do not consider chronic exposure to low intensity (non-thermal) exposures despite the overwhelming body of evidence of adverse health effects occurring at levels thousands of times below the existing standards[20,21]. Consequently many countries including (but not limited to) France, Italy, India, Israel, China, Switzerland, Poland, Russia, Hungary and Bulgaria have exposure standards well below the ICNIRP standards.

On 29th January 2015, France passed a bill banning wireless technologies including base stations, mobile phones, tablets and WiFi from childcare centres and nurseries[22].

As a result of the increased risk in glioma associated with mobile phone use, on the 31st May 2011 the International Agency for Research on Cancer classified radiofrequency electromagnetic fields used in wireless technologies as a Group 2B carcinogen, i.e. possibly carcinogenic to humans[23]. France and Belgium have consequently banned advertising mobile phones to children[24] and some governments including Germany, France and Israel are recommending replacing wireless technology in schools with hard wired options instead[25]. On 3rd July 2014, Telstra sent out a text to all of its users on how to reduce one's exposure to the radiation from their products. As the manufacturers of this technology are not required to prove safety, the burden of proof falls on governments and researchers to prove harm; something that may take decades to achieve, essentially exposing generations of children to a hazard that even the World Health Organisation has raised concerns about.

Synergism And Additive Effects

Whilst epidemiological data on the interaction between electromagnetic fields and other environmental agents are scant and inconclusive, the combined effect was first raised in 1974 by three Soviet researchers who observed that irradiation of tissue by pulsed radiofrequency sources cause cell membranes to become more permeable to chemical mutagens[26]. More recently, a systematic review of the combined biological and health effects of electromagnetic fields (EMFs) and at least one other agent was conducted using factor analysis amongst other methods[27]. This paper highlighted both the beneficial effects (accelerated fracture and wound healing, limb regeneration in amphibians, enhanced drug delivery and bacterial inactivation for prolonged food storage) and the adverse effects EMFs may have on biological systems when combined with other agents. Adverse health effects identified were the ability of EMFs to interfere with DNA repair mechanisms[28], enhance the effects of known carcinogenic or mutagenic agents[29], enhance oxidative damage and increase glioma incidence in workers who were also exposed to solvents, lead and herbicides[30] amongst other effects. Whissel and Persinger (2007) observed that very weak magnetic fields strongly potentiated the effects of drugs through opiate, cholinergic, dopaminergic, serotonergic and nitric oxide pathways and that these synergistic effects were several times larger than those evoked by the drugs alone[31].

Central to this combined effect is the ability of radiofrequency electromagnetic energy (RF EME) to increase the permeability of the blood-brain barrier (BBB); an intricate hydrophobic barrier that protects the brain from large proteins and water soluble chemicals through strict control of selective diffusion[32]. Some studies have reported no changes to the BBB permeability[33,34,35] whilst others have consistently reported increased BBB permeability after exposure to RF EMF[36,37,38]. The mechanism by which this radiation induces neuronal injury and increases the permeability of the BBB is suspected to be due to its ability to broaden and fracture intercellular tight junctions[39]. The impact of exposing children to wireless technologies that increase the permeability of the blood brain barrier and placental barrier to chemicals, heavy metals and microbes is essentially unknown and warrants investigation as it may provide important clues to the rapid rise in neurobehaviourhal disorders in children. A recent Korean study found that the ADHD risk associated with mobile phone use was primarily observed in children with higher blood lead levels suggesting that increased permeability to the blood brain barrier may be involved[40]. Despite this, this technology continues to be marketed and deployed in schools and to consumers, such that today's children are subjected to different frequencies that are thousands of times more levels of radiation compared to when their grandparents were young. Not surprisingly, Kostoff and Lau (2013) concluded that the combined effects of EMF with other agents were primarily synergistic in nature and should be the focus of a much more detailed study[41]. Similarly Verschaeve and Maes (1998) concluded "we believe that synergistic investigations deserve special attention… it may well be that a radiofrequency exposure alone is ineffective whereas this exposure might enhance the mutagenicity, carcinogenicity or teratogenicity of chemical or physical factors"[42]. This 'allostatic load' may be central to understanding how various risk factors interact to cause 'intermittent' autism and the wide array of symptoms amongst sufferers. This poses an important question: could the electromagnetic fields typically found in the built environment potentiate the effects of neurodevelopmental toxins commonly found in a child's home?

Children Are Not Little Adults

Prior to the thalidomide tragedy, it was widely assumed that harmful chemicals could not cross the placenta and that animal (rodent) studies do not reflect what happens in humans[43]. How things have changed! Extensive epidemiological evidence supports a causal relationship between prenatal and early childhood exposure to environmental toxins such as lead, DES and alcohol, with adverse health outcomes in children[44]. An emerging concern is the impact of endocrine disrupting chemicals during critical windows of development (which rodent studies adequately predicted) that at very low levels (non-monotonic dose response) may derail reproductive development.

Despite the fact that children are more susceptible to environmental hazards, there is no legislation, national program, policy, agenda or organisation that specifically addresses children's environmental health in Australia[45]. In contrast to adults, children have unique exposure pathways: in-utero (lead, mercury, PCBs, alcohol, PBDEs, alkyl phenols, DES, thalidomide, radiation) and breast feeding (susceptible to lipophilic chemicals including persistent organic pollutants, lead, mercury, nicotine, PBDEs and so on). Being at the end of the food chain, the body burden of chemicals in newborns is significantly higher kilogram for kilogram than most adults which is why the World Health Organisation use breast milk as a biomarker for the level of environmental contamination in the world[46].

According to Ginsberg (2002), children are more vulnerable to xenobiotics because they are in an anabolic state (they require more calories and water and are geared to absorbing nutrients very efficiently), phase I & phase II liver detoxification pathways are less efficient, the blood-brain barrier is not fully developed, and they have reduced renal elimination (reduced GFR)[47]. Their immune system is still developing which makes them uniquely susceptible to developmental immunotoxicants such as chlordane, lead and DES. The growth and development of their respiratory system is not complete until 18-20 years of age[48] which makes them more vulnerable to environmental tobacco smoke and mycotoxins[49].

Unlike adults, infants and children spend more time in fewer locations such as the bed, floor, high chair, and desk. This makes it even more important to investigate their exposure to hazards such as flame retardants which are an integral component of their bedding, low fire risk pyjamas and mattresses as well as to electromagnetic fields (the bed's proximity to fridge/oven and smart meter, wireless devices…), tap water (bathing and making infant formula) and associated use of personal care products as their level of exposure to these hazards may be greater. In contrast, school age children will be exposed to different environments depending on the school's proximity to major arterial routes, wireless technology and computers, pesticides and so on and so forth.

A child's respiratory rate is higher and their breathing zone is closer to the floor where dust and their associated contaminants (volatile organic compounds such as pesticides and flame retardants, house dust mites and microbes) are located. The Bhopal disaster in 1984 was a tragic example of children being more vulnerable as the 'dense' gas cloud stayed closer to the ground[50]. Pesticides and flame retardants are of particular concern as they are found in household dust. This may explain why polybrominated flame retardant levels in Australian children in the 0-4 years age group were twice as high as the 5-15 years age group and four times higher than the over 16 years age groups[51].

A US study conducted measured almost twice as many residues of metabolites of the pesticide chlorpyrifos in children aged between 6 and 11 than in adults[52]. Another threat to children's health is the exposure to the mercury vapour from a broken compact fluorescent light bulb as mercury is denser than air; the level of exposure closer to the ground is likely to have a higher concentration[53].

A child may ingest up to eight times more dirt than an adult due to their exploratory behaviour[54]. This hand to mouth activity may be a significant source of exposure for children 12 to 36 months of age as the house dust is often contaminated with numerous chemicals like PBDEs, lead and pesticides[55,56]. Dust sampling can be a useful indicator of exposure to toxins in the built environment, particularly for young children who are in frequent contact with carpets[57].

Children undergo critical windows of development which makes them especially vulnerable to endocrine disrupting chemicals, with strong data sets showing that exposure to PCBs, lead and methylmercury early in life cause cognitive and behaviourhal deficits in humans[58]. Longer life expectancies allow longer exposure to chemicals and wireless technologies and the development of diseases which have longer latency periods. Lastly, children do not recognise danger.

The Need For Further Research

Remarkably, the vast majority of hazards identified in this paper are found in the home and school environment where children spend up to 85% of their time. Despite this, few physicians in the medical or complementary therapy industries have an awareness of these hazards let alone why children are uniquely vulnerable to them, even though there has been a significant increase in data on this topic in recent times. There is definitive evidence that lead and mercury cause neurodevelopmental disorders, strong evidence that prenatal and postnatal exposure to pesticides and PBDE's may affect neurodevelopment and emerging evidence that radiofrequency electromagnetic energy used in wireless technologies may also be involved. Little is known about their interaction, synergistic or otherwise and many questions remain unanswered.

What is the body burden of neurodevelopmental toxins in Australian children?

Which neurodevelopmental toxicants are found in Australian homes and if so, at what levels?

Do these levels vary in healthy versus children diagnosed with neurobehaviourhal disorders such as autism?

Can radiofrequency electromagnetic energy used in wireless technologies potentiate the effects of neurodevelopmental toxins?

What strategies can be adopted to reduce one's exposure to these hazards?

Survey tools such as questionnaires that enable physicians and the public to adequately assess their exposure to hazards typically found in the built environment are woefully lacking. Technological advances however in the field of DNA sequencing (PCR), factor analysis and integrated environmental health impact assessments provide exciting opportunities to investigate the relationship between environmental hazards to childhood diseases.

Conclusion

Children live in a very different world compared to when their grandparents were young. The number of chemicals in their food, water and air has increased exponentially post WWII. In addition, wireless technologies have become an everyday part of their lives which, in conjunction with their increased body burden of chemicals may provide important clues to the pandemic of childhood neurodevelopmental disorders we are now seeing. Children's health outcomes could be improved if the interactions between multiple hazards during critical windows of development were better understood. Reviewing the various hazards likely to be involved in neurodevelopment does not prove that these parallels imply causality, rather it emphasises the complex nature of neurobehaviourhal disorders in children and the need for research in this area. The challenge for researchers is to create studies and/or models that reflect real life scenarios and consider the synergistic and additive effects of multiple hazards such as chemicals, heavy metals, biotoxins and radiofrequencies typically found in a child's environment. Integrated environmental health impact assessments, surveys and ongoing systematic reviews are needed as the issues concerned are complex and interwoven and are likely to have multiple causes, such that the interventions likely to arise from these outcomes may involve numerous organisations with far-reaching effects.

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